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DISCUSSION UPON THE PROPOSED INTEROCEANIC SHIP CANAL.

Special Meeting, Monday evening, December 15, 1879, at No. 11 West 29th Street, Chief Justice C. P. DALY presiding.

Present,—Gen. Geo. W. Cullum, U.S.A.; Gen. Q. A. Gillmore, U.S.A.; Signor de Franco; Horatio Seymour, State Engineer of New York, and James T. Gardner, Director of the State Survey; Major Sidney F. Shelbourne; Col. T. Bailey Myers; F. A. P. Barnard, President of Columbia College; Messrs. A. G. Menocal, Wm. H. Webb, A. L. Ford, A. J. Cotheal, Wm. L. Elseffer, Elial F. Hall, Wm. H. H. Moore, Cyrus Butler, D. Torrey, John Bogart, Secretary of the Society of Civil Engineers, and others.

Chief Justice DALY: It was suggested, at the last meeting of the Society at which this subject was considered, that it should be continued at the rooms of the Society. The fact that several gentlemen who are familiar with the matter are now in the city, and are about to leave in a day or two, made it necessary that we should call a meeting within so short a period as left no possibility of sending individual notices to our members, as is our custom. All we could do was to give notice in the evening papers to-day, and I am gratified to see that there is a larger attendance than we had reason to expect. We have here present several gentlemen who have made this subject of an interoceanic ship canal a matter of especial study, and their views upon it are necessarily of importance. I will ask Mr. A. G. Menocal, Civil Engineer, who is present, and who is to be in the city but a day or two, to give us his views as to the proper canal to be constructed, and some account, if he will do so, of the Nicaragua route, of which he made the survey.

Responding, Mr. MENOCAL opened the discussion of the evening by the following remarks:

It will not be necessary, I suppose, for me to enter into any description of the state of Nicaragua, which doubtless is well known to all here. The Lake of Nicaragua, which is at the summit of the proposed canal by the so-called Nicaragua route, is a body of water 110 miles in length, by 30 miles of average width, having a superficial area of 2,700 square miles. Its elevation above the sea at high tide is 103 feet, and at mean tide 107 feet. The depth, from a point 1,200 feet east of its west side to within about nine miles of its outlet, the San Juan river, is at all points as much as 30 feet, and in some places as much as 150 feet. Several lines were run from the lake to the Pacific ocean to find the lowest depressions in the supervening mountains, and two were found that seemed to offer the best prospects ; in one of these the point of greatest elevation above the level of the lake was 43 feet, and on the other it was 134 feet. The length of the former is 18½ miles, of the latter 16⅓ miles. The latter, the shortest, was recommended, for the reason that though the summit was higher, there is on the other line a small stream, or river, carrying 5,000 cubic feet of water per second, that would have to be received into the canal. The level of the lake is to be extended westward eight miles to the slope down to the Pacific. From that point to the sea the ground falls at the rate of nine feet to the mile. The locks are to be so disposed that there will be no less than 2,500 feet between any two of them. A ten-foot lift was adopted, not because the foundations were not firm enough to give a larger, but because this was found about the mean lift of all the locks then in operation in the United States, and was deemed sufficient. Possibly, on the final location of the line, a larger lift might be adopted, and the number of locks reduced. This total lift of 103 feet will be overcome by ten locks. There will also be a tide-lock, to overcome the tide of the Pacific, which at the maximum is 8½ feet, with the medium 5½ feet. The level of the canal there is such that vessels can come in at any time from that side without double lockage. That is, we do not need to have a second system of locks, as would have to be adopted in a canal opening from the east at a lower level than that of the sea. The exploration of this line was extremely careful. In some places elevations were taken every 25 feet, and borings were made every 1,000 feet, particularly on the sites of the locks, to ascertain what foundation we could depend on for the construction of the locks. All the small streams that would cross the line of the canal are to be provided for by culverts, through which their water would be discharged into the Rio Grande, the stream running through the gap along the line of which the canal was located ; and so perfect is the system of drainage afforded by that river, that the water from any part of the canal can be turned into it, and the desired lock be left perfectly dry. The proposed width of the canal is generally 72 feet, and the slopes of rock are ¼ to 1 above the surface, and ½ to 1 below the surface. In earth, the slopes are 1½ to 1. I have merely given this general description upon such points as have suggested themselves to me, and will be glad to answer any questions that any of the gentlemen present may desire to ask me, before we proceed to the description of the canal on the other side of the lake.

Q. by Mr. GARDNER: What is proposed as the actual width of that part of the canal, surface and bottom?

Mr. MENOCAL: The width varies. In this deep cutting of rock it will be 60 feet at the bottom, 90 feet wide 10 feet above the bottom, and 106 feet wide at the surface. In earth, the bottom width will be 72 feet, and the surface 150.

Q. Is there any tunnel from the lake?

Mr. MENOCAL: No, sir; the elevations are not sufficient between the lake and the ocean to require a tunnel, being only 43 feet on one line, and 134 feet on the other.

Q. The depth of the water, I presume, is 24 feet?

Mr. MENOCAL: No; 26 feet in depth on the whole line of the canal. On the west side, where the canal will leave the lake, there will be an excavation, under water, for 1,200 feet, commencing with zero, and extending into the lock at that depth of 26 feet. That will be as far as we have been able to learn from the indications in gravel and rock.

Q. What is the nature of the rock?

Mr. MENOCAL: Trap rock, the same as we find all along the line; basalt and greenstone. That is, it is the rock generally found, though in some places there is limestone. There is a large bed of limestone at this point, La Flor, between the summit and the Pacific.

Q. Will any of the mountain streams be taken into the canal?

Mr. MENOCAL: No; it is not proposed that any of those streams shall be taken into the canal, but that it shall be fed exclusively from the lake. For that reason the higher elevation was adopted, on account of the better drainage. It is, however, proposed now to make further examinations toward ascertaining the possibility of diverting the Rio Grande into the lake; in which case, the line of the lowest elevation will be recommended as the best for the construction of the canal, as it would save no less than six millions of dollars in the estimates.

Q. Where do you get water for your summit level on that line?

Mr. MENOCAL: From the lake. Its level is extended clear to the slope down to the Pacific. It is the summit, and there is no doubt about the supply of water being ample. In the stated area of the lake is, of course, comprised the area of the other and smaller lake, Managua. The present connection between them is only open when they are full, and the water from this lake does not at all times flow into Lake Nicaragua, but that is a matter easily remedied, and the area of the water-shed properly embraces the water-shed of that lake.

Q. by Gen. GILLMORE: What is the greatest rise and fall of that lake?

Mr. MENOCAL: Four and a half feet seemed to be the maximum. We examined well the water-marks, and from all the indications they afforded, we arrived at the conclusion that that was the maximum.

Q. What is the annual rain-fall there?

Mr. MENOCAL: It varies from 45 to 50 inches. For six months we have hardly a drop of rain. In the rainy season we have frequent showers at night, rains occasionally in the day-time, and sometimes there are rain-storms that last two or three days.

Q. What is the size of the locks you contemplate?

Mr. MENOCAL: The locks proposed are 400 feet long, by 70 feet wide; but that length may be increased to 450 or 500 feet if it is deemed desirable. There are, however, few vessels now afloat that will require above 400 feet, and I suppose that will answer for all practical purposes.

Q. Are there many mountain torrents to bring in debris?

Mr. MENOCAL: No, sir.; not into the canal, which is kept entirely free from surface drainage.

Q. What kind of a harbor have you at Brito?

Mr. MENOCAL: A very small and insufficient one. We will have to build a harbor there.

If there are no more questions to be asked about this portion of the work, I will now pass on to the consideration of that part of the canal on the other side of the lake. The San Juan river is the outlet of Lake Nicaragua, and carries off, when the lake is full, from 12,000 to 15,000 cubic feet of water per second. The river falls but two feet in 28 miles, and then 12 feet in the following nine. There are two rivers emptying into the lake—Rio Rama and Rio Frio—almost parallel with the San Juan, but running in the opposite direction, both of which are large streams.

You will perceive that the water-shed of the river, between the lake and where we leave it, is very small. The depth of the stream will have to be increased, by dredging and blasting under water, to a mean of six feet. The maximum will be at Toro rapids. The fall of the river to those rapids is two feet only, and at the rapids we have a fall of six feet from there to Castillo, where we propose to build the first dam. This dam is proposed to be 940 feet long. The rise of the water will be 18.87 feet in front, and 13.32 below, by the second dam. The second dam will be 1,196 feet in length, and 31 feet high above the bottom of the river. The rise of the water here will be 22 feet above and 12 feet below. The third dam will be 824 feet in length, and 33 feet, or nearly 34 feet above the bottom ; the rise in front 26 feet, and below 16 feet. The last dam will be 1,000 feet in length, and the water will be raised in front 30 feet, the fall 23 feet. In the other dams, the fall will be equal to the lock in the short canal that is going to be built around the dam, which in every case is ten feet and a fraction—ten feet and nearly ten inches. Below Toro rapids, there will be no dredging of the river, because the present depth of the river, increased as it will be by the raising of the water by the dams, will be sufficient, except in two places, to give the required 26 feet. Between the last two dams the river is very deep, as much as 80 feet, which would bring the bottom 30 feet below the level of the ocean.

At this point the Rio San Carlos comes into the San Juan. This is a silt-bearing river, a torrential river, and for that reason the canal is there taken from the line of the San Juan and is built inland. Owing to this high hill right opposite the mouth of the Rio San Carlos, it is proposed to extend the slack-water navigation to a few hundred feet below the mouth of that river, where the last dam will be constructed, and a new channel is proposed for the Rio San Carlos, to divert it and make it empty into the Rio San Juan below the dam, so as to preserve for the canal only the clear water from the lake.

These short canals around the dams are to be about a mile in length ; one is to be three-quarters of a mile, and the others between that and a mile and a quarter. The dimensions of these sections, or small canals, are to be similar to those of the one proposed on the other side of the lake. Now we come to the consideration of the section between where the canal leaves the river and Greytown.

Q. by Gen. GILLMORE : What is the extreme length of this slack-water navigation ?

Mr. MENOCAL : Sixty-three miles, with four dams.

Q. by Mr. GARDNER: How far from the lake to the first dam ?

Mr. MENOCAL : Thirty-seven miles ; so that really the level of the lake will extend on the Pacific side eight miles to the slope, and 37 miles on this side.

Q. What is the discharge of the San Juan ?

Mr. MENOCAL : It varies. Above this point (indicating on the map) at a high rate from 12,000 to 15,000 cubic feet per second ; below this point, sometimes 22,000 to 24,000, because the volume is increased by this large river, the San Carlos, and others. Besides the San Carlos, as you will see, we have three other rivers coming into the San Juan, below where the canal leaves it. The larger tributaries all come from the Costa Rica side. The largest are the San Carlos and the Serapiqui.

Q. Then from where you enter the lake on the west side there is unimpeded navigation for 93 miles ?

Mr. MENOCAL : Fifty-six and a half, lake—37, river—all at the same level—and eight on the other side ; so that really the navigation is uninterrupted for 102 miles of summit level, 103 feet above high tide.

Q. What is the extreme rise and fall of the slack water of the San Juan in times of flood and drought ?

Mr. MENOCAL : The maximum rise is between four and a half and five feet. The lake acts as a large distributing reservoir, so that the floods have little effect on the rise and fall of the river.

Q. What is the average breadth of the river ?

Mr. MENOCAL : At the broadest point, between the last two dams, it may be, in some places, only about 600 feet. That is where it has such very great depth. Above the third dam there is an average of 1,200 feet, except in one place, where it contracts to 840 feet. That is at Machuca. Above that it is all from 1,200 to 1,500 feet wide.

Q. What is the depth, or what will be the depth, when the improvements are completed?

Mr. Menocal: 26 feet.

Q. And the width at bottom?

Mr. Menocal: 80 feet, with slopes of 6 to 1 where dredging is required. For a vessel drawing 20 feet the channel width there would be 152 feet, and for one drawing 24 feet would be 104 feet. I do not see, really, why the width of this canal should be any larger than the one on the other side, because there are no winds to be feared, because the river is protected by the high hills and forests on the sides, and the current is not over half a mile per hour. The prevailing breezes are from the northeast. Here, in the lower canal, where the line of the dredging to the dimensions indicated extends, the mountains and forests so shield a vessel that there is but a very light breeze. It is so also on the river, and there is no fear of winds throwing the ship from one side to the other of the canal.

Q. What water will you have on the dams?

Mr. Menocal: I have computed very closely the water at the top of the dams at both high and low water. The thickness of the volume of water on the first dam will be 2.93 feet, on the second 2.56 feet, on the third 3.28 feet, and on the last 2.92 feet. The velocity of the water in the river will be, in the first section, .46; in the second and third, .54; and in the fourth, .49; so in only two sections will the velocity of the current be a fraction over half a mile per hour. The flow of the river is, in the first three dams, as near as we could come to it, 12,453 cubic feet per second in the first, and 12,953 cubic feet per second in the second and third; while in the fourth it is 13,206 cubic feet per second. So the difference in the volume between the first and last reach of the canal in that slack-water navigation will be only about 800 cubic feet per second, which is caused by the small streams coming in between the lake and the Rio San Carlos.

Q. Is that at low or at high water?

Mr. Menocal: At low water—I have it also for high water, but fail to find it in the notes I have with me. But I know positively, without having the data to confirm my memory, that at no time will the water on the top of the dam be over four feet in thickness at high water. As you see, it is only the last dam that will have to stand the pressure of the water raised in front. Borings were made at the sides of the river where the locks are to be located, and the character of the rock was found to be the same as on the other side of the lake—that is, wherever rock was found ; but we saw very little rock on this side of the lake, only in the bottom of the stream, in reefs, here and there, and in the rapids already spoken of. Here, in the rapids, we did not take any borings in the bottom of the river, but when the lead struck hard bottom we estimated it rock, and where it went through soft material we estimated earth or clay.

Q. What harbor is there on the Atlantic side ?

Mr. MENOCAL : There is no harbor. One will have to be made. I am coming to that directly. We are now arrived at the section between where the canal leaves the river and Greytown. It follows the line of the river to this point, as you see on this map, a distance of 24 miles, and thence goes by almost a straight line to Greytown. The line was at first laid out here, along and over these hills, but afterwards I made a complete survey of that part of the country and found a lower path, by which the line can be located at a reduction on the former estimates for cutting, of from one and a half to two millions dollars.

Q. What is the estimated total cost of the work ?

Mr. MENOCAL : Fifty-two millions, to which is to be added the customary allowance of 25 per cent. for contingencies—call it, altogether, including the harbor improvements necessary, $65,000,000. The harbor at Brito will cost $2,337,000 ; that at Greytown, $2,822,000. The cost of harbor improvements, such as will be here required, will be not great, for the reason that we will have abundance of rough stone, convenient of access, from the excavation of the canal, and plenty of excellent wood near at hand.

Q. What is the rise of the tide on the Atlantic side ?

Mr. MENOCAL : One and a half feet.

Q. What drainage have you on this side ?

Mr. MENOCAL : It varies, but is always amply sufficient (because the river is), though constantly following the canal, at varying distances from it. The bottom of the canal is, however, generally, above the bottom of the river, and the streams coming from the north it is proposed to pass under the canal by means of siphons, except some very small ones that may be received into the canal.

Q. What is your project for the harbor on the Atlantic ?

Mr. Menocal : We propose to build a jetty. At Greytown the sea strikes the sand beach at an angle of about 45 degrees, and is constantly shifting the sand from east to west. This has caused the formation of the sand bar now closing the harbor. It is proposed to build a jetty out to a depth of 30 feet at low tide, and let these drifting sands from the northeast accumulate in the angle between the coast and the jetty. In course of time it will fill up there, but then, by a further extension of the jetty two or three hundred feet, we would increase to almost double the area of deposit, and the harbor would be preserved from the shifting sands for a certain number of years. The artificial beach thus formed by the accumulation of the sand may be so shaped that it will be either perpendicular to the prevailing winds, or so inclined to them that the sand, instead of moving toward the entrance of the harbor, will be shifted to the south toward the Colorado, when the harbor may be considered permanently restored. The Colorado river takes $\frac{29}{30}$ths of the water of the Rio San Juan, only $\frac{1}{30}$th going to the harbor of Greytown. It is proposed in the plan for the improvement of the harbor so to obstruct the channel of the lower San Juan, by means of trees and other obstructions, as to throw all the silt-bearing water of the San Juan into the Colorado, and receive into the harbor only the clean water of the canal, drawn from Lake Nicaragua. I have here plans showing the alterations in the harbor of Greytown from 1809 to the present time, and, if you will look at them, you will see at once that the bar has been formed in the way I have described.

Q. Is the mouth of the San Juan river permanent in its location, or has it moved ?

Mr. Menocal : Well, it is permanent now, so far as its emptying into the lagoon is concerned. It does not empty into the ocean, but into the lagoon. In the wet season, when the accumulated waters bank up in the lagoon, then it cuts an outlet through the sand-bank to the sea, but as soon as that pressure is removed that outlet is quickly closed again by the sands drifted by the action of the wind.

Q. What is your estimate for the removal of earth from the canal per cubic yard ?

Mr. Menocal : Thirty-five and forty cents per cubic yard.

Q. And how much for rock ?

Mr. Menocal : $1.25 and $1.50, and under water $5. The blasting and dredging of rock under water will be done in the Rio San Juan before the water is raised by the dams. I think, however, that if it be desired, the dams can be built at the same time the dredging and blasting is going on, by leaving sluices sufficiently large to carry the volume of the river. After all the dams are completed, these sluices—which will be provided with gates—can be closed at once, and then, as the water has to be banked up to the lake, I calculate that it will take about four months before the water comes to the top of the first dam. During that time the sluices and openings will be closed with masonry, and, before the full pressure comes upon them, will have ample time to settle.

Q. What is the material you will employ in the locks and dams?

Mr. MENOCAL: Concrete. It is difficult in that country to find dimension stone. The country rock will make a nice material for concrete work, but it would not do for cutting into dimension stone.

Q. What is the lowest temperature there in winter?

Mr. MENOCAL: About 71°, and in summer it rises to 81°. The variation is only about ten degrees in the year.

Q. Have you examined the old structures on the Isthmus, between the lake and the Pacific, to see if they are cracked by earthquakes?

Mr. MENOCAL: Yes; and they are not at all affected from that cause. They cannot have been injured and repaired, for they are entirely neglected by the Indians; yet they are in as good condition as they were, presumably, when the Spaniards left them.

Q. Do you anticipate any danger to the locks of the canal from the action of earthquakes?

Mr. MENOCAL: Decidedly, I do not. I do not know that earthquakes there ever do any damage to life or property, or that they ever have the slightest effect of altering the water supply in rivers, lakes or wells. But even if the wall of a lock should be cracked, it will be a very simple thing, and readily executed, to repair it.

Q. Are there, properly, less apprehensions of danger from earthquakes there than in other parts of the Isthmus?

Mr. MENOCAL: Not less than in all other parts, but much less than in some others. For instance, in San Salvador they are much more violent and frequent, and in Guatemala and in parts of the United States of Colombia.

Q. Have you examined the ruins left by Walker at Grenada, to note their condition, as to whether they had been affected by earthquakes or not?

Mr. MENOCAL: I have. They stand to-day just as he left them; those, at least, which were allowed to remain as ruins. The houses were rebuilt, but the churches were not, and their bare blackened walls, standing alone and devoid of any support or braces, rise to a height of, I should say, forty feet. I have examined them very carefully, and did not find a crack in them. Some of the towers were partially blown down then by powder, and look as if they were likely to tumble down at any moment. One, especially, seems threatening to fall with the wind. Yet they stand there as they have stood since 1854. Those are forty-two miles from the line of our proposed canal. In the town of Rivas—two and a half miles from the canal—they have many stone houses, and about ten years ago they completed a stone church there, which had been building during thirty or forty years—one which would be a noteworthy stone church anywhere—and it has never received any injury from earthquake shocks, nor have the stone houses about it.

Q. Those Spanish ruins at Grenada, Castillo and San Carlos must be over one hundred years old?

Mr. MENOCAL: Not less than three hundred years, probably, some of them. I had occasion to show to the United States commissioners dams that had been built surely over one hundred years ago, which are standing to-day, though not for any present practical purpose, which have never been repaired, yet which manifest no imperfections which can be detected by the closest examination. They were built originally for the purpose of damming up water to be used in the manufacture of indigo, and were abandoned, and have been standing there for one hundred years, perhaps. We saw a gentleman who lived close to the dam near Rivas, and he said it had been there since he was born—he was not less than seventy years old—and before his time, but he could not say how long, as his father never told him when it was built. Yet it is now in the same perfect condition that it was, presumably, when first built, with no cracking, no imperfections and no leakage. Yet it has no apron, and the water has a sheer fall of 15 or 20 feet to its base. Its length is 75 feet. That shows, to my mind, not only that earthquakes there will do no injury to constructions of this character—the locks of our canal, for instance—but that the material we have there for the construction of the work is of the best quality.

Q. What material did you say you proposed to use for locks?

Mr. MENOCAL: Concrete; and I suppose the lime of the country would be sufficient.

Q. What sort of wood have you?

Mr. MENOCAL: Oh, excellent—of various kinds, with Spanish names that I do not recall at this moment.

Q. Are those old Spanish works of concrete?

Mr. MENOCAL: Rubble masonry, with mortar between; the spaces among the large rough stones filled in with smaller ones and mortar.

Q. by Gen. GILLMORE: At what do you estimate the cost, per cubic yard, of this construction?

Mr. MENOCAL: From $7.50 to $9 per cubic yard for the locks, and $12 per cubic yard for the dams, on an average. To be explicit, take lock No. 2 as an example: concrete and foundation, $7; lock walls, $8; lift walls, $8; rubble masonry, $7.50 per cubic yard. For the dams across the San Juan the estimates are: rock excavation, $5; hydraulic concrete, $12; rubble masonry, $15; concreting abutments, $8; coping (dressed stone), $20, per cubic yard.

Q. You can get all the materials there at hand?

Mr. MENOCAL: All the materials. The excavations of the canal will furnish the stone, and the lime of the country will answer every purpose. They have built a small water-works at Masaya, in Nicaragua, which lifts the water 224 feet; and they have constructed a reservoir or tank in the centre of the town, where they store the water to a depth of 20 feet. The thickness of the wall of this tank at the bottom is only 4½ feet, hardly the theoretical thickness required for the best possible construction of such a wall, yet this is built only in the roughest way, of rubble work, and though it has been in use four or five years, there is not the slightest sign of any imperfection from weakness, earthquakes or any other cause.

Q. How about the harbor on the Pacific side?

Mr. MENOCAL: On the Pacific side, we propose to build a jetty here (indicating on the map), starting from this point, 800 feet in length, extending out to 25 feet depth of water; and another jetty here, running westward, to prevent the sand shifting into the harbor. Then the harbor will have to be dredged. No rocks will be encountered there. I have tested to a depth of 30 feet under water and found the bottom all sand. The materials for the jetties will be taken from this hill, on the coast, which is nothing but trap-rock.

After these surveys were completed, the government ordered a commission of two army officers, an assistant to the coast survey, and two civil engineers, to go over the line and verify the work. The line was located only two years before, so that the stakes and bench-marks marking the locks, cross-sections for dams, etc., were still preserved and were carefully examined by them. Also, through our suggestion, several portions of the line were carefully re-surveyed by them to determine the accuracy of the surveys which had been made. All were found to be perfectly accurate in every point. Bench-marks were found about every 2,000 feet along the line, and the profiles were found to be the actual facts in the careful surveys we had made. After they were made, I was in the country several times, in connection with the improvement of the Rio San Juan and harbor of Greytown, and also with reference to a proposed improvement connecting the two lakes—Nicaragua and Managua. Then I made still further careful surveys of this portion of the line, and I know that modifications of the original survey can be made that will reduce the cost of the canal perhaps ten or fifteen per cent. I am sure that any change made in the line, in accordance with my suggestions, will tend to reduce the estimates.

Q. In what year were the estimates made?

Mr. MENOCAL: In 1872.

Q. What was Mr. Child's estimate?

Mr. MENOCAL: His estimate was for a canal only 16 feet in depth, and I think it was $34,000,000. Perhaps it was only seventeen or eighteen millions; I do not remember now.

Q. What is the radius of your shortest curves?

Mr. MENOCAL: 2,200 feet. That is the minimum adopted, and was recommended by naval officers whom I consulted on the subject. They said that the versine of an arc with a chord of 500 feet in such a curve being only 4 feet, there would be no difficulty in taking a ship 400 feet in length around a curve of that radius. An enlargement of the radii of all curves to 5,000 feet would not increase the estimates more than one and a half or two millions of dollars.

Q. Did you see any external indications of earthquakes along the line of the canal?

Mr. MENOCAL: None whatever, sir; and I would like to call upon Mr. Ford, an expert engineer who is conversant with that country, to say what is his information upon this subject of earthquakes.

Mr. A. L. FORD: It is commonly said there, and reported in the authorized government history of the country, that there has been no instance of loss of life or property by earthquakes.

Q. by Mr. MENOCAL: You went through Leon?

Mr. FORD: Yes; and I saw no marks or imperfections caused by earthquakes. I also examined with interest some very large concrete-walled tanks—indigo vats—that have been built several hundred years, but show no signs of cracking.

Q. by Chief Justice DALY: Does this apply to the whole country?

Mr. FORD: It is so said. I do not know of my own knowledge, as I did not go through the whole country.

Q. by Chief Justice DALY to Mr. MENOCAL: What are the most prominent engineering objections to the Panama route?

Mr. MENOCAL: I suppose the Chagres river offers the most really serious one, and the rise and fall of the Pacific tide and the prevailing calms at Panama the next. The Rio Chagres, in the dry season, is a very small stream, say 250 feet wide and two feet deep. I have waded across it many times. But in the rainy season it becomes a torrent and rises in less than a single day to a maximum of 40 feet. In that case the width of the river is some 1,500 feet, and the volume of water carried fully 160,000 cubic feet per second. The bed of the river is 42 feet above the sea, and as it rises 40 feet in flood at the point where it is proposed to be taken into the canal, you see it will have to be received into the canal with a fall of 82 feet, or say 78 feet, making allowance for the decrease due to the velocity of the water as it approached the precipice, and for the head of water above the ocean level after falling.

Q. Does not the Chagres river bring down much debris?

Mr. MENOCAL: Oh, yes; very much—decayed vegetation, mud, trunks of trees, houses even. In the recent floods it carried away two whole villages. I see reports that it even carried away an iron tank that was 17 feet above the level of the Panama railroad track.

Q. What is the rock formation there—on that route?

Mr. MENOCAL: Sandstone, conglomerate, limestone, coral, and in the upper Chagres large masses of a very soft limestone, so soft that with a half-pound hammer you could break off large pieces of it. And it is not a continuous mass. On one side of the river you will see a vertical, or even overhanging, limestone wall, 80 feet high, and on the other side of the river four or five feet only of limestone, with 20 feet of clay on the top of it; and in a few feet farther you will find the limestone wall on the other side of the river where the clay was, and the clay on the side where the limestone was.

Q. How does M. de Lesseps propose to deal with it?

Mr. Menocal: At the Paris Congress they proposed to build an artificial channel from where they intend to take the river-bed for the canal to the sea.

Q. How far is that?

Mr. Menocal: It is 30 miles by railroad; I do not know how far by their canal. They will have to cut through some very high hills and mountain spurs projecting on both sides of the river to its very banks, in order to straighten its tortuous course to meet the practical requirements of a ship canal; and they will have to build walls across the lower valleys between the high hills extending to the river. As the cross-section of the river is 15,000 square feet, and the water-section they propose to give the canal is about 2,000 square feet, the new channel for the river will have to be no less than 7½ times the proposed section of the canal.

Q. Do you think the enormous waterfall there would have any effect upon a marine railway?

Mr. Menocal: I think it would, as has been proved by the great damage done to the Panama railroad by the recent floods of the Chagres river.

Q. The canal, then, would have to discharge 160,000 cubic feet of water per second in time of flood?

Mr. Menocal: Of course, since it is to receive the volume of the river; and what difficulties may have to be encountered in confining so great a body of water, moving with such velocity, in an artificial channel, we may well appreciate, since we all know how hard it is to divert even small streams and confine them to new channels.

Q. And the velocity is very great?

Mr. Menocal: No less than seven miles per hour with the present fall of the river, and as the canal is only a few hundred feet from the river, and the water of the river is several feet above that in the canal, we may well fear that at any time the river may overflow its artificial banks and flood the canal.

Q. by Chief Justice DALY: Will you not explain a little more fully the difficulties to be encountered at the mouth of the canal—I mean of the Panama route—and the means by which the projectors of that route propose to overcome them?

Mr. MENOCAL: I do not know what plans they propose to adopt.

Q. You suggested a difficulty from the character of the coast?

Mr. MENOCAL: If they build their canal at the level of the sea at Panama, they will have to excavate in the Bay of Panama one and a half miles under water, and in the harbor of Colon they must also excavate under water a long distance to get sufficient depth for their canal.

Q. And they will require steam vessels to get sailing vessels out of the Bay of Panama, will they not?

Mr. MENOCAL: In regard to that, I will request Col. Myers to read a paper I have here--a letter from Commodore Maury—with some remarks thereupon by Captain Pim, of the Royal Navy.

Col. T. BAILEY MYERS read the following:

"30 HARLEY ST., CAVENDISH SQUARE,
"LONDON, July, 1866.

"MY DEAR CAPTAIN PIM,—I had occasion some years ago to study, more or less closely, almost every route between the British possessions on the north, and the Isthmus of Darien on the south, whether rail or canal, that had up to that time been attempted or projected across the American continent. Owing to the character of the researches with which I have been for more than twenty years engaged, my attention was directed to those routes rather in their physical and commercial aspects, than to their topographical features, or to their facilities of construction.

"The great importance of one or more *good* commercial highways across Central America being admitted, the whole question as to route resolves itself pretty much into a question of the cost of construction, and the facility of ingress and egress by sea to and from the opposite termini; the latter is an affair of winds and currents. Their influence is powerful. Panama has the advantage of land transit; Nicaragua has the advantage in winds, terminal ports and climate. The first is obvious; but to place the latter in a clear light, a little explanation may be necessary. * * * I have spoken of a calm-belt about the equator ; Panama is within its range. Owing to the contour of the Central American isthmus, the height and direction of the mountain ranges by which it is traversed, and the influence of these upon winds, this calm-belt is greatly enlarged on the Pacific or lee side of the isthmus. It is difficult to convey, to one who has never experienced these calms, an idea of the obstinacy with which they vex navigation. We are all familiar with calms at sea, which last for a few hours, or even a day; but here they last for days and weeks at a time. I have known vessels going to or from Panama to be detained by them for months at a time. * * * On one occasion the British Admiralty, wishing to send one of their sailing vessels into the Arctic ocean from Panama in time to save the season, had her towed by a steamer through this calm-belt, and carried 700 miles out to sea before she could find a breeze. * * * These remarks apply to the approach and departure by sea to or from the Pacific terminus of any route across the Isthmus of Panama or Darien, and even with greater force to the Atrato and others on the South American side of Panama. In short, the results of my investigation into the winds and currents of the sea, and their influence upon the routes of commerce, authorize the opinion which I have expressed before, and which I here repeat, namely: if nature, by one of her convulsions, should rend the continent of America in twain, and make a channel across the Isthmus of Panama or Darien, as deep, and as wide, and as free as the Straits of Dover, it would never become a commercial thoroughfare for sailing vessels, saving the outward bound, and those that could reach it with leading winds. Steamers would and coasters might use it, but homeward-bound vessels in the China, India or Australia trade rarely. * * * We come now to the Nicaragua routes. Of these there are several. Though longer across from ocean to ocean than Panama, some of them have already, and with a degree of success by no means discouraging, competed with it before the world for public favors. * * * Skillful engineers, both French and American, have examined them [the engineering difficulties and topographical features of this Nicaragua route]. Those of both nations report gradients gentle enough for a canal. In truth, the lakes, their distance from the sea, and their height above it, indicate that the summit-level is to be attained without any very steep ascents.

" It is to this part of the isthmus, too, to which we must look for a route which shall best fullfil the present requirements of commerce between the two oceans, as well as for transportation and travel between the Pacific shores of North America on the one hand, and the Atlantic shores both of Europe and America on the other. * * * Vessels under canvas would, in the main, do the fetching and carrying for the Nicaragua route, which, for reasons already stated, cannot be done for Panama. The aggregate amount of this trade is immense, and it is neither accommodated for Panama, nor Panama for it. * * * Therefore, returning again to the physical features of the Panama route, as I promised to do, we can now compare more in detail than I have yet done the advantages possessed by each, as far as those advantages are influenced by facilities of navigation, by the elements, by salubrity of climate, and by the dictates of commerce. The French and English Admiralty charts give the most accurate information that I possess concerning the harbors at the opposite ends of the two routes, Panama and Nicaragua—I mean as to mere anchoring ground, depth of water, and shelter afforded. It is proper to remark here, that I was a great friend, an earnest advocate, and an active supporter of the Panama road, giving it in 1849 the preference over all other isthmian routes. At that time my 'wind and current' investigations had not extended into the Pacific ocean, and the discovery of those causes which make the approach and departure to and from the Bay of Panama so very difficult for sailing vessels had not been sufficiently established to give them their proper weight. * * * You will observe, at a glance, that the Isthmus of Panama, or Darien, is, on account of these winds and calms, in a purely commercial point of view, the most out-of-the-way place of any part of the Pacific coast of intertropical America. * * * 'Lieutenant Maury,' remarks Mr. Hull, master of H. M. S. *Havannah*, 'truly says that the passage under canvas from Panama to California is one of the most tedious, uncertain, and vexatious that is known to navigators.' Realejo (Nicaragua) is in the northern verge of these calms (Panama), and where they have nearly ceased to be vexatious to the navigator any season. Here, then, is the physical advantage in favor of the Nicaraguan route, for which it is difficult to find the money value. * * * The transit route of Nicaragua is exempt from those heavy drawbacks of dampness and disease. It passes through a salubrious climate. The soil is productive; its pastures abound in cattle. I never heard of any disease peculiar to the country, or of especial virulence there.

[Signed] "M. F. MAURY."

Col. MYERS: Upon the foregoing letter, Captain Pim goes on to remark, in a paper read by him before the British Association in Sheffield, this year, as follows:

"Commodore Maury tells us in the plainest language, that if nature, by one of her convulsions, should rend the continent of America in twain, and make a channel across the Isthmus of Panama, or Darien, as deep, and as wide, and as free as the Straits of Dover, it would never become a commercial thoroughfare for sailing vessels, and I have only to endorse this opinion; for of all parts of the world I have ever visited the calms in the Bay of Panama are the most vexatious and enduring. It therefore seems the clear duty of a Central American Isthmus canal projector to decidedly avoid this locality. Under these circumstances it becomes necessary to look elsewhere for a more feasible line of transit, and (once more relying upon the letter of Commodore Maury) the route from the Atlantic by way of the magnificent Nicaraguan lakes to the harbor of Realejo, seems that which is adapted for the required purpose; for, as Commodore Maury states, and I quite agree with him, it would be impossible to exaggerate the money value of having, as he describes it, a fair start and approach by means of the little monsoons of that coast.

"Assuming that arrangements can be made for transferring the public favor—or perhaps I ought to say that of M. de Lesseps—from Panama to Nicaragua, I think it may be desirable, as I have been many, many times over that route, to give a general outline of its features, and I will conclude by offering a few suggestions, which I trust may prove of utility to those who will embark in the grand enterprise of effecting a junction between the Atlantic and Pacific oceans. The great difficulty to be overcome in the construction of a canal across Nicaragua is in the making and maintaining the harbor of Greytown on its Atlantic terminus. My friend, the late Mr. Robert Stephenson, the great engineer, when I was with him in Egypt in 1858, used to say that he was acquainted with the deltas of all the great rivers of the world, but that he was not aware of a single instance in which a harbor was maintained at the mouth of such rivers. Now, the Rio San Juan de Nicaragua has a delta at its mouth, but no other delta in the world is so capricious. In 1856 a squadron of Her Majesty's ships rode securely at anchor in the harbor of Greytown; but in 1860, when I was stationed as senior naval officer in that locality, the sand-bar which made the harbor stretched across very nearly from shore to shore, leaving only sufficient depth of water for the very smallest coasting craft. A few years later there was again a considerable opening, and so matters go on, but now for some time it has been completely closed. A strong norther is sufficient to close the harbor, while a high river will reopen an entrance. Mr. Robert Stephenson's dictum, therefore, as to the enormous difficulties to be encountered in the attempt to form a harbor at the delta of any great river is more than borne out in the case of Greytown; although I am well aware that an exception has occurred to this ruling in the case of the Mississippi, where Mr. Eads has succeeded in obtaining a depth of 27 feet, under high pressure from Congress; but the problem is, how to *maintain* that depth at anything like a paying cost? If the engineering difficulties could be overcome in forming and maintaining a harbor at Greytown, the other obstacles to the opening of the canal from ocean to ocean would be found of very secondary importance; but to my mind the cost of such an undertaking would completely paralyze the enterprise."

Q. by Major SIDNEY F. SHELBOURNE: Can you tell me, sir, whether Captain Pim does not now hold a concession for a canal by way of Nicaragua?

Col. MYERS: I cannot, sir. I have simply been requested to read this article, and know nothing farther of Captain Pim's interests in or associations with any interoceanic ship canal enterprise.

Mr. THOS. DE FRANCO: He holds a concession for a railway instead of a canal, I understand.

Major SHELBOURNE: I hold in my hand an article in which it is stated that there are now three concessions for Nicaragua canal routes—one to M. de Belly, one to Captain Pim, and another the one in which Commodore Vanderbilt was once interested.

Col. MYERS: I take it, sir, that it is entirely immaterial to the discussion of the questions at present before us who holds concessions, or is going to furnish the money to build the canal. What we are endeavoring to arrive at is a knowledge of the feasibility of the several routes, their difficulties and advantages, by such information as Mr. Menocal is now endeavoring to give us from his surveys upon the route he advocates. When we have heard from him we hope to hear from others, until we have collected all the information possible of value for the world. It will then be time to discuss other questions. There have been for years, as we are all aware, many projects, in some cases sustained by official grants for various forms of transit, none of which were carried out, perhaps for want of money. The present discussion has again called attention to them. If any of them are an improvement to those accepted by the French Congress, or approved by the American government, the projectors will have the opportunity of settling their relative merits amongst themselves, and with those who appear to be acting with an assurance of means to build, and therefore must have the privilege in the end of selecting their route. Having no interest myself, present or prospective, in any project, I feel at liberty to express this opinion.

Mr. MENOCAL : The reason I asked the reading of the letter and accompanying matter was simply for the purpose of placing before the meeting the opinion of so great an authority as Captain Maury.

Q. by Chief Justice DALY : Do the trade winds blow regularly, on both sides of the isthmus, at the termini of the Nicaragua route?

Mr. MENOCAL : Yes, sir.

Q. And how far down do they extend on the Pacific side?

Mr. MENOCAL : Not so far as Panama. A sailing vessel generally gets about as far as Costa Rica without difficulty.

Q. And with those trade winds, sailing vessels can at all times approach either the Pacific or the Atlantic end of this canal?

Mr. MENOCAL : Yes, sir.

Q. It is published that your estimate for passing a vessel through the canal is thirty-eight hours?

Mr. MENOCAL : Yes, sir ; that is correct.

Q. At what rate of speed would that be?

Mr. MENOCAL : Three miles per hour in the canal, eight in the river and ten in the lake, the usual speed of a steamer at sea. The time allowed for passing through the locks is twenty minutes. There are some gentlemen here who have some experience with canal locks, from whom I would be glad to hear an opinion as to whether this is an over-estimate or not. Mr. Seymour and General Gillmore can speak as authorities on this subject, I believe.

HORATIO SEYMOUR, JR.: I do not know that I am particularly posted in this matter, any more than are a number of other engineers here.

Mr. MENOCAL: Only in regard to the time required to pass the locks, I should like to hear your opinion.

Mr. SEYMOUR: I should say twenty minutes for each lock was a proper estimate of time. It takes a boat eleven minutes to go through one of the Erie canal locks. At the Sault S'te Marie it takes twenty minutes. Col. Weitzel estimates twenty minutes as quite sufficient.

Gen. GILLMORE: Twenty minutes is an ample allowance of time.

Q. by Chief Justice DALY: I understand these locks are made for 3,000-ton ships. Can you slow up a 3,000-ton ship, get it through the lock and start it again in twenty minutes?

Mr. MENOCAL: That is what more experienced engineers than myself in canal operation believe is practicable.

Q. Are there any locks in the world, of the same magnitude as these are intended to be, which would afford a precedent as to time?

Mr. MENOCAL: Not except in the enlargement of the Welland canal, which at least approximate. They are 270 feet in length, by 70 in width. Here in the United States I think we have locks 400 feet long, but not so wide or so deep. The Ohio locks, I think, are only twelve or fourteen feet in depth. It is in the handling of the ship, where you have to swing it around, that time is required, and that will be all that will cause delay in the operation of the tide lock—getting it into the axis of the lock. But in a canal where the line of the vessel is in the axis of the canal, all we have to do is to stop the velocity of the ship, close the gates, and then, when the gates before her are opened, the ship starts again, promptly, and without any swinging around. The opening and closing of the locks can be done in a very short time.

Mr. GARDNER: There can hardly be greater difficulties in passing ships through ship canals than are encountered in the St. Lawrence canal, yet nine thousand were passed through there in one year.

Mr. Menocal: And they have there but one system of locks, have they not?

Mr. Gardner: I think most of them are single.

Mr. Menocal: The engineer of the North Sea canal, Mr. Conrad, who is in favor of M. de Lessep's plan, told me they could pass seventeen ships during the hours of the day—they do not operate the locks at night—through the two great locks of the North Sea canal; that is, large ships of four or five thousand tons. If there were that number of ships to pass through our canal, with a system of single locks, we could carry four or five times the probable trade of the canal.

Q. I understood from Lieut. Wyse, in a series of interviews I had with him last winter, that M. de Lesseps was opposed to the lock system, because there was no precedent by which to satisfy owners of vessels that they would be safe in entrusting their vessels and cargoes to such an extensive system of lockage as proposed by the Nicaragua route, or by the plan he himself proposed by way of the Atrato.

Mr. Menocal: It is to be remembered that M. de Lesseps is not an engineer, and never had anything to do with canals until he was a financial promoter. I have here the opinions of M. Cotard and M. Lavalle—two prominent French engineers, who took an active part in the construction of the Suez canal. They find no difficulty in building a canal on the plan proposed by the Nicaragua route, and before the Paris Congress advocated the construction of that canal. M. Lavalle has subsequently stated before the French Society of Civil Engineers that the efficiency of the Suez canal would have been increased if a tide lock had been built on the Port Said side of the canal. Neither of those engineers anticipate any difficulties in working a canal with locks, provided they are properly built and sufficiently supplied with water.

Mr. Gardner exhibited a profile of the Welland canal improvement. He said: This represents a canal 27¼ miles long. You will observe that there is a perfect staircase of locks, to carry vessels of 2,000 tons, and the total lockage, by this staircase, is 326¾ feet, or three times as high as from the Atlantic to the summit-level of the proposed Nicaragua canal. These locks are 240 by 40 feet, with a depth of 14 feet. The total height of the lockage between the lake and Montreal, is about 550 feet. The Canadians built their first ship canals in 1829, and after about twenty years' experience with the system, were so well satisfied that they commenced enlarging and improving them, and they have expended about thirty million dollars in this work of enlarging these canals so as to make them practicable for 2,000-ton vessels. The Canadian engineers have more experience than any others with long ship canals, and demonstrate their success most practically by the enterprise with which they are extending and enlarging their serviceability. The total expenditure of Canada on this long ship-canal route, when it shall have been completed, will be over $54,000,000.

Chief Justice DALY: Within $10,000,000, nearly, of the Nicaragua canal's estimated cost.

Mr. GARDNER: Yes, about the same as the Nicaragua canal proper. But here this lockage, in a single place, within a distance of seven miles, is three times as great as that required on the Nicaragua canal. The locks are not as large as it is proposed those shall be, but they are large enough to carry 2,000-ton vessels, and these vessels succeed each other rapidly, one right after another. Through the old Welland canal they could put through 4,400 vessels in a single year, but through the new system 9,000. I telegraphed yesterday to the Secretary of the Department of Railroads and Canals, at Ottawa, to know the actual time a vessel made in going from Port Colborne to Dalhousie, and he sent me back word that he had transmitted full information by mail—which does us no good this evening. I had hoped to be able to present the information now, but will have to defer it until another time.

Q. How many locks are there in that staircase?

Mr. GARDNER: They have 27 in the flight, of about 12 feet lift.

Major SIDNEY F. SHELBOURNE: It is disagreeable to have to differ from a gentleman of such experience and ability as Mr. Menocal, but I shall have to say something regarding the calms in the Bay of Panama. I am not in favor of M. de Lesseps's route. I think it impracticable, financially and scientifically. I am in favor, however, of the San Blas route, which opens into the Bay of Panama, and I have taken particular pains to investigate that matter of the calms in the Bay of Panama, because I have heard it reiterated, again and again, what difficulty vessels would have in passing into and out of that bay. It is true there is a belt of calms, extending from about 4° north latitude to 14° or 15° north latitude, and it extends all the way across the Pacific ocean to the China seas. It varies in its width, sometimes extending not higher up than 8° or 10°, sometimes to 14° or 15° north latitude. Within this larger limit is the Pacific terminus of the proposed Nicaraguan canal. The San Blas terminus is in about 8° north latitude. This belt is called by sailors "the doldrums," and is not wholly calms, but full of variable, shifting, light winds and calms. I have taken the opinion of sea captains in the California trade—have gone on their ships and enquired about it—and I have consulted with Mr. Charles Frederick Elwell, President of the Maritime Association of this port, and head of a very old shipping firm that sent out the first supply vessel to California. He said that in a single year his firm had sent as many as 125 to 130 sailing vessels to Panama and Aspinwall, and "they would just as lief go to Panama as to any other port on the coast ; there was no difference." Maintaining the view I had fixed in my mind that there was in the Bay of Panama, during about one third of the year, a season of almost perpetual calm, I asked him if there was not a time when there were nearly constant calms in the Bay of Panama, but he wouldn't hear to that. Now Mr. Elwell has no interest in this matter, and he said that his firm " would as lief send vessels into the Bay of Panama as any other port on the coast."

But now, suppose the argument was true, that there were calms in the Bay of Panama, and that the fact was due to that bay being in the belt of calms or equatorial "doldrums," would it not then be apparent to you that, if this belt extends across the Pacific, then vessels passing through the Nicaraguan canal, and coming out near the northern verge of that belt, if bound for any South American Pacific port, Japan, China, or Australia, would have to pass through this belt of calms—through the whole of it ? But vessels going through by the San Blas, or Panama route, would only have to pass through one-half of it, admitting the full extent of their argument.

Captain Pim and Lieutenant Maury doubtless stated this as a matter of scientific inquiry, but those men whom I have consulted have realized it, experienced it in their business as a fact, and are, surely, competent to judge of its importance. Now is book knowledge, or scientific experiment and knowledge, to be compared with the practical experience of sea captains and shipping houses who have carried and sent vessels by the hundred into this very port? Which is worth more, the opinion of one party or of the other? With regard to this Nicaragua route, the subject is so large, the figures so extensive, the plans so elaborate, that if a person has not studied them by days and weeks a very plausible and fair-seeming statement of the different parts of the plans would pass muster, and be accepted almost anywhere, even with an audience as intelligent, and capable of judging of things, as this audience is. But let us look at them a little. You will see, from Mr. Menocal's statement of the width of the bottom of his canal, in rock, that it is 60 feet; the slope of the wall one vertical to one horizontal. That is, at four feet from the bottom you will have a width of 64 feet.

Mr. MENOCAL: Excuse me a moment. Sixty feet is the width of the bottom of the canal at a depth of 26 feet; at a depth of 16 feet the width is 90 feet, and on the surface of the canal it is 106 feet. But it will be observed, by looking at the section of the water-prism of the canal, that by continuing the slopes proposed of ½ to 1, from the surface of the water to the bottom of the canal, the bottom width will be 72 feet, or more than the Suez canal, and the increase in the excavations will be insignificant, probably not more than 500 cubic yards in the whole extent of rock excavation in the canal.

Major SHELBOURNE: Even allowing that change to have been calculated in the plans and made, the canal 72 feet wide upon the bottom, with this rise of one foot vertical to one-half foot horizontal, would still, at a height of four feet from the bottom, be but 76 feet wide. But vessels of three, four, and five thousand tons, such ships as would be employed in this interoceanic trade, have a beam of 40 or 45 feet. Now two vessels of that size, each drawing 24 or 25 feet of water, could not meet and pass in that section of the canal, because the outer side of each would graze upon the unexcavated rock. The canal is not wide enough on the bottom in the rock section, and any just estimate of its cost should be based upon a very material enlargement in this direction. Another thing that materially affects the estimates is, that while the canal is calculated on a depth of 26 feet on this route, the calculations for the San Blas and M. de Lesseps's routes are made upon the basis of a depth of 28 feet. Between the lake and the first dam, Mr. Menocal says, is 29 or 30 miles, and the excavation would be made to an average depth of six feet. Now, then, in that part of the river we have, according to Mr. Menocal's own estimate, some 834,000 and odd cubic yards of rock excavation required to get the depth of 26 feet of water. Then you have a width of 80 feet to obtain ; and, understand, that excavation in the rock is not all at one point, but at various places along a distance of some 28 miles, in removing reefs of rock spread out in the river, in some instances only a little to come off, in others more. He says that excavation can be made before the dams are completed—that is, he would have that rock excavation to do under a depth of, say, 10 to 15 feet of water, and that water the current of a river, before a dam is built upon it. My experience shows me that it would be easier to blast out and remove rock from a depth of 26 feet in still water, than under 10 or 14 feet where you have a current of three or four miles an hour, or even less, to contend with. But, granting him the most favorable conditions in still water, Mr. Menocal has put his estimate for this rock excavation much too low. He has placed it at $5 per cubic yard. Now we all know that here in New York harbor, where there is competition and the best appliances, for simply lifting rock from the bottom, and taking it away after it has been blasted out by Gen. Newton, in his work in the East river—and that not in Hell Gate, but from other obstructions he has been removing—the cost has been something like $4.50 per cubic yard. The latest estimate, I believe, was $2.26 per ton, and two tons are calculated to the cubic yard. That would make a difference in Mr. Menocal's estimate of $6,424,245, taking the quantities of necessary excavation he has calculated upon. If you should go to 28 feet in depth, to put figures on a comparison with those of other routes, as all submarine reefs increase in contents more or less largely as they go down, you would have a still greater quantity, an indefinite but vast quantity, to add to the present estimates. Suffice it to say, taking the 10,000 and odd cubic yards of rock excavation at the west side of the lake where the canal passes down to the Pacific, and adding the number of cubic yards in the river where the slack-water navigation is to be, the whole quantity would be 856,566 cubic yards. In this paper he has undertaken to justify the figures he has placed, by saying that Col. Child's estimate in 1851 was from $2.50 to $5 per cubic yard. He has also estimated the gravel and sand dredging in the river, at a depth of 9 to 14 feet, at 2,180,589 cubic yards. Now, if you will look on the map, you will see the curves and angles of that river, and I should like to ask any engineer, who has practically excavated such a work, whether a width of 80 feet, following the course of such a crooked river, would be wide enough to allow vessels to pass without grazing their sides and bottoms on the rocky sides of that tortuous cut. Again, in regard to the open cut. He has made the sum of that 14,677,389 cubic yards, and he has told you that he has estimated the cost of that at $1 to $1.25 per cubic yard. Now, all engineers who have done any work on the isthmus—among them Col. Totten, Mr. Evans and other gentlemen of practical experience—will say to you that that price is wholly inadequate for that work. In some particular localities it might be sufficient, but not here. To bring the figures up on the basis of the estimates on the other routes would add to that estimate for that open-cut work the sum of $24,535,469, making those two items—the six million dollars necessary increase on the item of rock excavation in the river and these twenty-four millions—something over $31,000,000. Adding that—with the customary percentage for contingencies—to their present estimate, would bring the total cost up to $104,421,790. Moreover, on the canal on the Atlantic end, there is a stretch of seven miles that will have to be constructed through a swamp imbedded with trunks of trees—a perfect network of trees, and stumps, and other material. The removal of this is not so difficult as the fact of maintaining a canal through such a swamp, with such a section as Mr. Menocal has estimated for it. A slope of 1½ to 1 is wholly inadequate. In such a swamp, where it is more or less mud, the material taken out in the excavation of that canal would have to be put far back on the bank. Now, then, to increase the estimate for that part of the canal—those seven miles through the swamp—necessarily to increase it to obtain a work capable of being maintained, to make the slope 4 to 1 and get a width of 100 feet on the bottom, would add some 9,000,000 of cubic yards (double what he has allowed) to the excavation. And when you have done that you will still have to line those walls with rip-rap to get them to stand, besides putting the material taken from the cut far back from it, to prevent its weight and slipperiness pushing it back into the canal. This part of the canal passes through two or three small lakes, and there is a river called the San Juanillo that crosses it almost at right angles. What provision has been made for that river I do not know, and cannot find out from the estimates.

Again, in the lake, there are seven miles, from Fort San Carlos on the east side out into the lake seven miles, where the excavation of the mud has to be to a depth of 10 feet on an average. Mr. Menocal has said that the width of the bottom there was calculated to be 80 feet, with a slope of·4 to 1, and he thought, because vessels would not meet with any wind in that part of the canal, that that bottom was wide enough. Now, in all government works, it has been calculated that a channel, where the excavation is only 3 to 6 feet upon an average, and it is desired to make it navigable for large ships, should have a width of 300 feet at least. I will refer you, by way of illustration of such a work, to the channel which is excavating in the Patapsco river for the improvement of Baltimore harbor, under the direction of Col. Craighill. They commenced that with a width of 500 feet, and have been increasing it.

Mr. Menocal says sailing vessels would probably be able to sail across the lake and not be obliged to take a tow. But this evening he states that that channel would be wide enough because there would not be any wind there. How then could sailing vessels go across the lake without any wind? They would have to be towed across the lake. But, to increase the width of that channel to a width of 300 feet and provide as would be necessary in such soft material, you would have to excavate 12 feet, with a slope of 3 or 4 to 1. A friend who has sailed across that lake tells me that the paddles of light-draft side-wheel vessels would blacken the water by stirring up the mud from the bottom, it was so soft. So, to maintain that cut there, you would have to be continually dredging to keep it 300 feet wide, and you would have to buoy it to make it convenient or safe even for steamers. As regards the harbors on both sides you have had sufficient information, and are able to judge of the difficulties in the way of constructing and maintaining them. I do not see any difficulty in creating a harbor on the Pacific, but I do see difficulty, not in creating, but in maintaining one on the Atlantic side, and if any of you will see the length of the line of coast directly east from Greytown, you will appreciate how long a breakwater will have to be built, how far out it will have to be built, before the direction of the prevalent wind will be at right angles to the bank that is formed between the breakwater and the present coast.

Mr. Menocal: How far?

Major SHELBOURNE: I think the coast extends almost directly eastward from the entrance to Greytown harbor for a distance of a mile to two miles.

Mr. MENOCAL: And how long will the jetty then have to be?

Major SHELBOURNE: Well, that is a mere matter of engineering calculation.

Mr. MENOCAL: Oh! and I suppose you have not studied that?

Major SHELBOURNE: Oh, I don't assert that a harbor cannot be maintained there, but any jetty built will be only temporary in its effect, and it will continually have to be extended.

Mr. MENOCAL: The question is how far it will have to be extended before we have the sands drifted by the action of the winds at right angles with the present coast?

Major SHELBOURNE: Well, my impression is that the coast extends a mile, or a mile and a half directly east. Now, if the winds strike that coast at an angle of 45°, that jetty will have to be extended to make a right angle with the coast. If Mr. Menocal will be present at any future discussion, I will be careful to make the estimates, and tell him how long the jetty will have to be before the conditions he desires will be attained.

In regard to the matter of locks, and the time of passing through them, that is a matter for every engineer to judge for himself. I want to say, however—though I do not wish to be understood as offering it as a valid objection against the lock system—that if you calculate the area of the present pipes that Mr. Menocal has located in his locks to fill them, taking the velocity of the inflowing water at 10 feet per second, it will take, as you will find, some eighteen minutes for the water to fill them. I do not say those pipes cannot be increased, but I do say the present estimates are wholly inadequate. I think it is fair to remind the gentlemen present that the commission of which Mr. Menocal speaks, said that, as far as the scientific work in the surveys was concerned, they found no fault with it, but at the same time they say—and Mr. Menocal has so admitted in a paper he wrote for *The Engineering News*—that this commission found that in some instances the prices put upon this work were not altogether adequate.

Mr. MENOCAL: I think you are in error, sir. I did not say, "the commission," but "some members of the commission." The fact is, that there was but one out of the five, Major McFarland, who entertained that impression, but in writing that article I did not wish to seem personal, and so wrote "some of the members," instead of "one of the members," which would have been correct.

Major SHELBOURNE: I do not stand here to correct the gentleman as to what he said on a former occasion. I simply say that to bring the prices on a par with those upon which the estimates of the other routes are based, is to add for two items alone an increase of about thirty-one million dollars to his estimates.

In regard to this matter of earthquakes in Nicaragua, and the different parts of the isthmus, the fact appears to be this: When you take the very narrowest parts of this isthmus, as it is at San Blas, and very little more between Panama and Colon, you find that it is not altogether free from slight shocks, or tremblings of the earth, but they were never known to have done any damage. You know some years ago, Caraccas, which is on the body of South America, had a very severe earthquake, in which the whole city was destroyed. I have not enough data by which I can say that my remark will be borne out by experience or scientific conclusions, but it appears to me, from the data I have seen and the information I could gather, that where the continents begin to widen out, so as to form a broad area, that earthquakes are more numerous and more severe. When you get into the body of South America the earthquakes are sometimes very disastrous, and you know earthquakes are very severe in Mexico. The idea seems to me to be this: Here you have a narrow region of isthmus with more or less depth of ocean on each side, and, as an earthquake must be due to internal commotion of the earth—volcanic or whatever you choose to call it—and will be disastrous in proportion to the resistance offered to that force finding its exit on the line of least resistance; so, if you take the isthmus at San Blas—1,500 feet high and very narrow—there it would seem the earthquake force would find its way out without any great resistance, and consequently without provoking any very great effect, but in South America it would have to exert a greater power to find the line of least resistance and effect its exit. So above in Nicaragua also, where the isthmus is wider.

There are other points, but I hardly feel like taking time this evening to develop them.

Mr. MENOCAL: I would like to say, in regard to the gentleman's proposed alterations in my estimates, that from all the information

I have been able to obtain, I am led to believe that the excavations, under water as well as out, can be executed along the whole route for the prices stated in these reports, and a very responsible person here in New York has told me they would be very willing to take the contract for all the rock blasting and dredging at the prices estimated.

As to the winds on the lake. I have said, and I say, that the winds do not prevail on that portion where the lake would have to be dredged, as that part is shielded by mountains. It would therefore be necessary for a vessel to be towed along the river and into the lake until she got a fair wind, beyond this sheltered corner, and then her way would be open for her all across the lake, for progress by the aid of her own sails.

As to the channel through the swamp, it is not proposed to bank the excavated material, but to dump it in the little lakes and the lower channel of the San Juan.

Q. What is the material ?

Mr. Menocal : Sand and clay, and as to a doubt of its standing a slope of 1½ to 1, I will simply say that the natural banks of all these lakes, as they stand, have a slope of ½ to 1, so that they have deep water very close to the edge. In that little lake (indicating upon the map) you have ten feet depth of water within five feet of the edge, and the center depth is 16 feet. All this material, as has been said, it is proposed shall be dumped into these little lakes and the channel specified. There is no proposition to form dykes on the sides of the canal.

Q. How high are the natural banks around those lakes ?

Mr. Menocal : On the south and west sides they are high, though I do not remember the exact altitude now, but all this (indicating the other margins on the map) is low land.

Q. How far does that river extend across the channel, and what is its character?

Mr. Menocal: It is simply an outlet of the Rio San Juan, and it is proposed to cut it off altogether, which can be done very easily.

Q. Do you propose to blast any rock in a current like that at Hell Gate?

Mr. Menocal : Oh no, not at all. There is a short place where we might have to blast at a depth of nine feet, in a current of five miles an hour, and as we blast away the rock which acts as a dam, the current will increase, but it can be at no point so violent as to offer any serious obstacle to the work.

Q. You have spoken of it as trap rock. Is it at all similar in character to that about here ?

Mr. MENOCAL: Oh no. It is loose and fractures easily, while this you have to encounter here is very hard and compact.

Q. Hard rock, like granite, would increase the cost of removal ?

Mr. MENOCAL: Yes ; naturally. But I can say that responsible persons here are willing to take the contract for all that work at the prices named in the estimates. Those estimates are correct, and no engineer of reputation, conversant with the facts, has—heretofore—criticised them.

Mr. A. L. FORD: So far as it affords an indication of the actual cost of earth excavation in that country, I will say that a large contract has just been made in Nicaragua for the construction of 80 miles of railroad, and the contract has been taken by Mr. Norris. His basis of figures for the earth work is on 30 cents per cubic yard for all kinds of earth, not merely light loam, but stiff clays and some swamp; and he based his figures on calculations including the rainy season and a prospective increase in the price of labor—for the entire labor market of that country is affected by a contract of such magnitude as building 80 miles of railroad.

Mr. MENOCAL: I would like to call the attention of engineers to the fact that, in the construction of the proposed canal across Nicaragua, the work is not concentrated at any particular point, but extended along the whole length of the line ; so that the men can be put to work at the same time from one end of the canal to the other, and the work can be completed in a relatively short time as compared to the time that would be required to build a canal by either the San Blas or the Panama routes, where, on account of the proposed tunnel and of the deep cuts, only a limited number of men can work at once.

Chief-Justice DALY : It is now twenty minutes to eleven o'clock. This discussion will be continued next Monday evening, until which time this meeting will stand adjourned.